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TPF-C Performance Modeling

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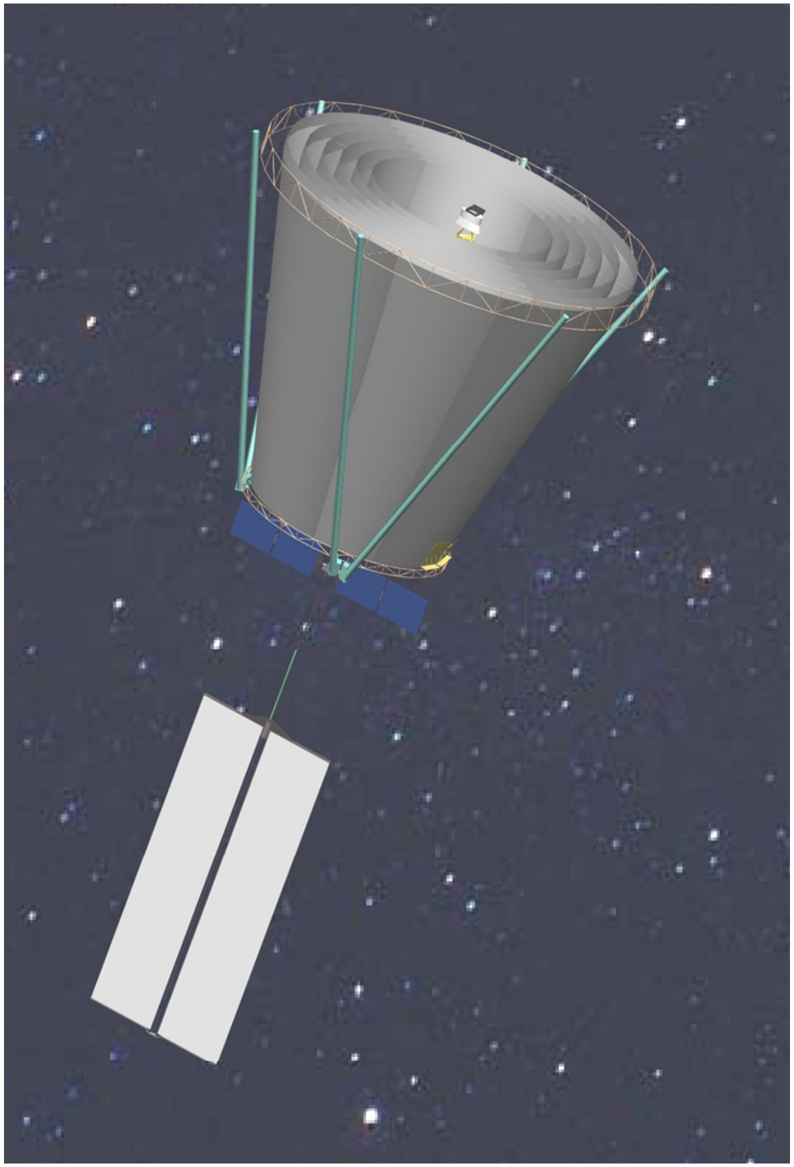

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Error Budget Models

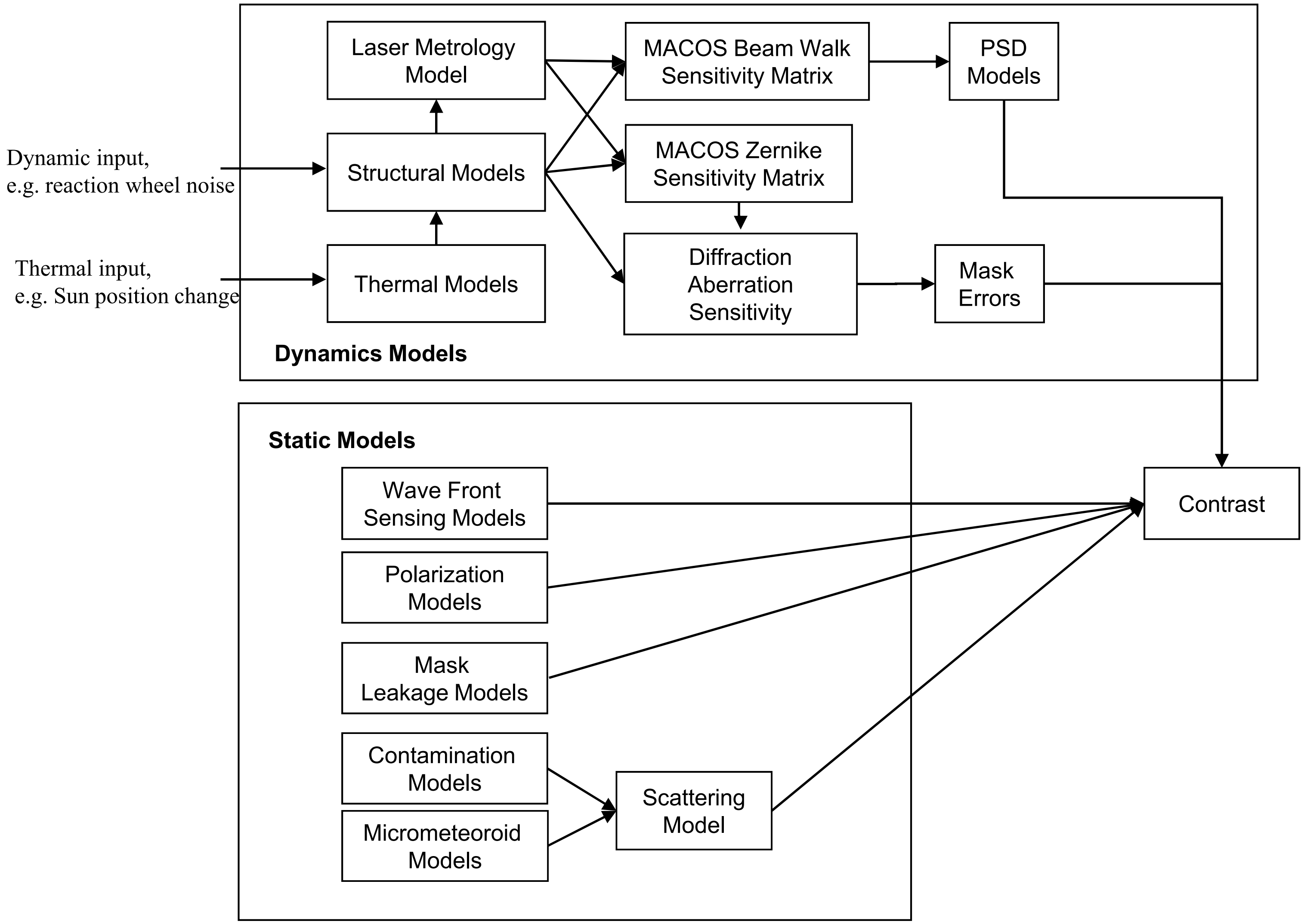

Figure 3. Models used to calculate static and dynamic contrast.

Static and Dynamic Terms

$$\text{Contrast} = I_s + \langle I_d \rangle$$
$$\text{Stability} = \text{sqrt}(2I_s\langle I_d \rangle + \langle I_d^2 \rangle)$$

	I_s = Static Contrast	I_d = Dynamic Contrast
Now we have Much better knowledge of:	Wave Front Sensing Wave Front Control Gravity Sag Prediction Print Through Coating Uniformity Polarization Mask Transmission Stray Light Micrometeoroids Contamination	Pointing Stability Thermal and Jitter Motion of optics Beam Walk Aberrations Bending of optics Aberrations
In 2005, we said:	Every item is unknown territory, new technology. Most are bandwidth-dependent	Solve with Design and Engineering, linear modeling. Bandwidth independent.

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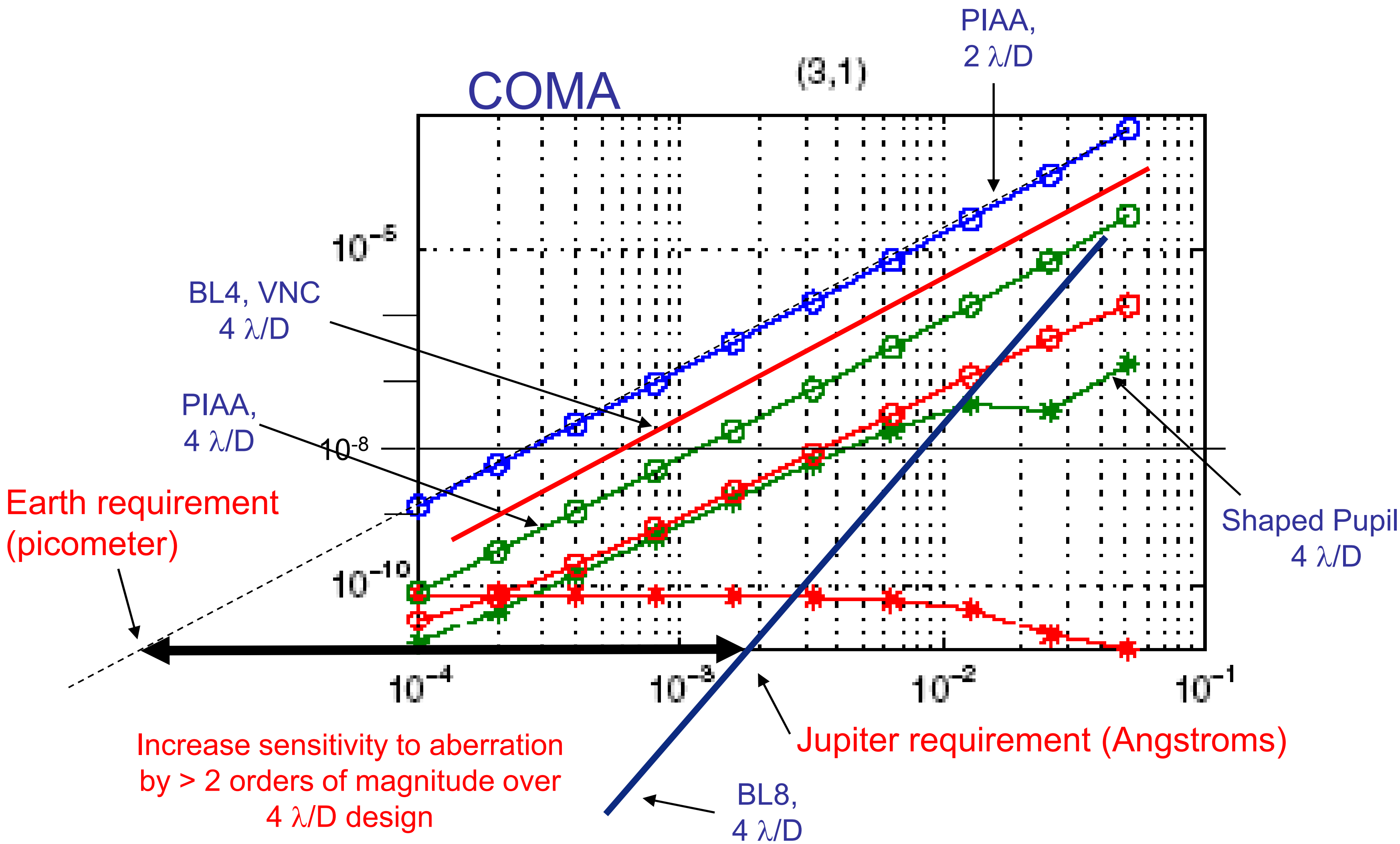
Aberration Sensitivity at 2 λ/D



Increase sensitivity to aberration by > 2 orders of magnitude over 4 λ/D design

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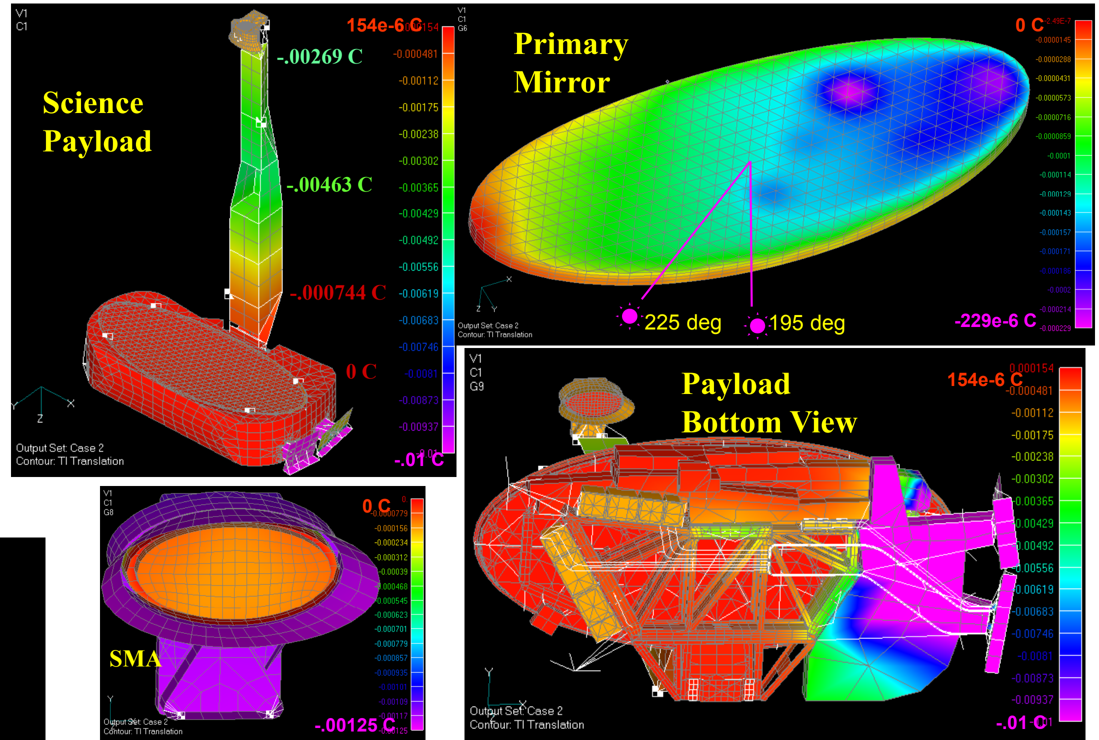
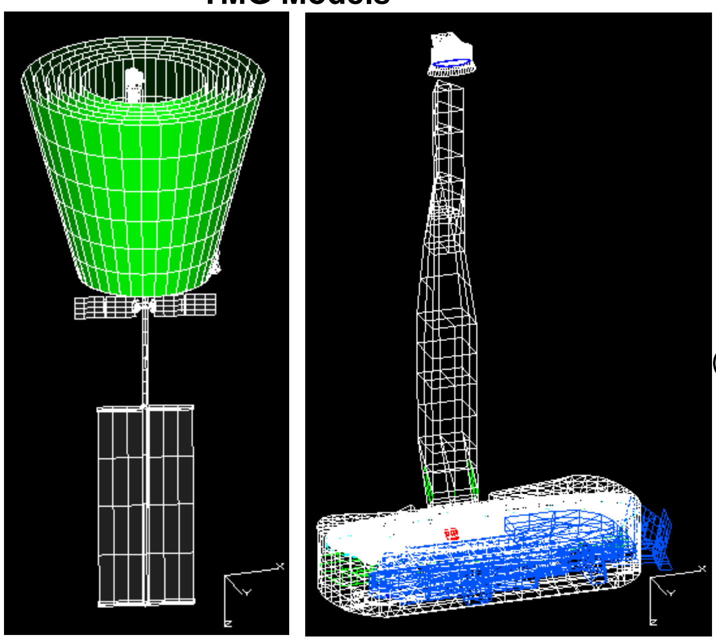
Executive Summary: Thermal Performance Models and Analysis

- Evaluated Thermal Tools:
  - TSS/SindaG, TMG, IMOS
- Thermal Model & Run Information is provided
- Performance evaluation: Dither angle from 195º to 225º is worst case
- Evaluated Temperature Control Heater Powers

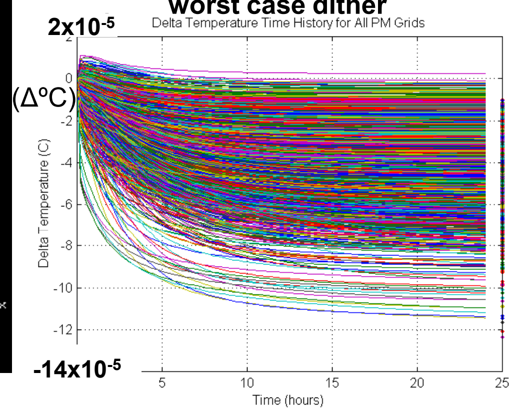
Dither Angle from 195º to 225º (worst case)



TMG Models



Transient results – all PM nodes, worst case dither



- Conclusions:
  - Even with worst case conditions, appear to be meeting requirements from Error Budget

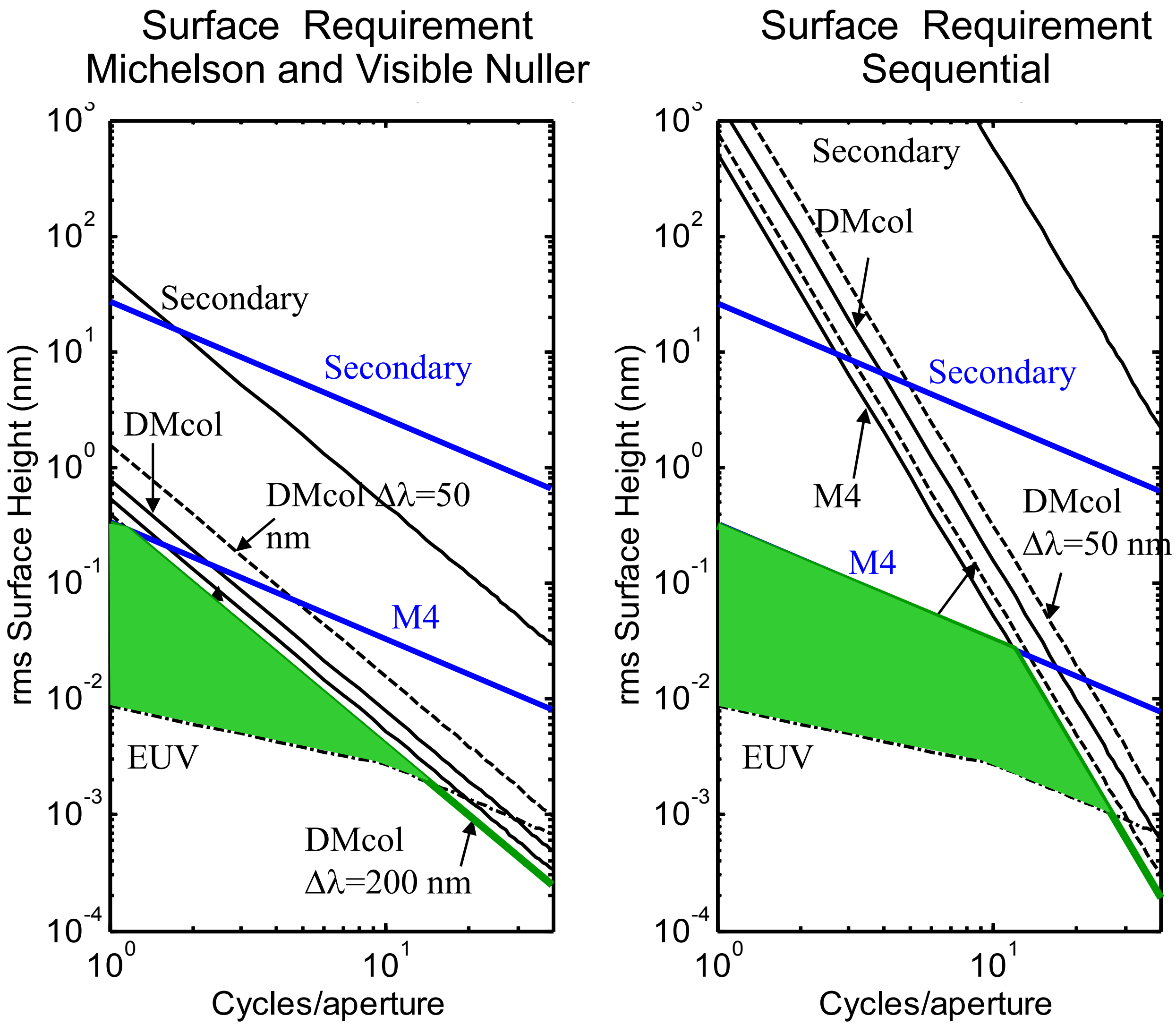
Surface Requirements

Blue = requirement due to finite star size

Black = requirement due to propagation effects

Green = requirement due to propagation effects

Fill = easier than state of the art



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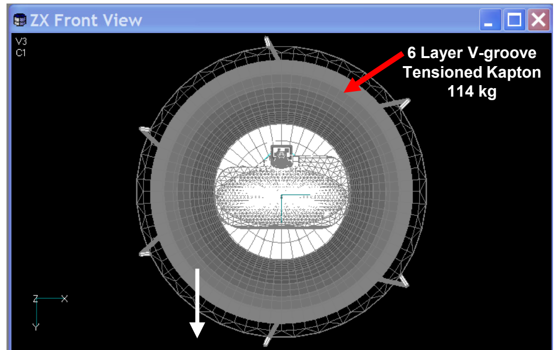
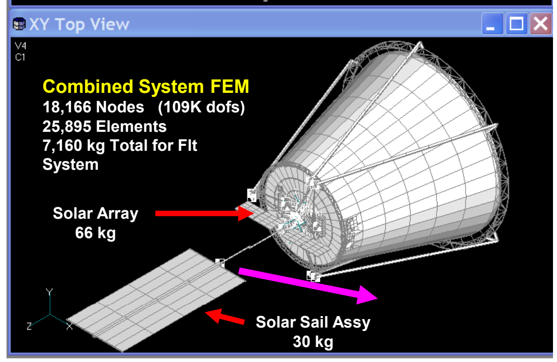
Executive Summary: Structural Performance Models and Analysis

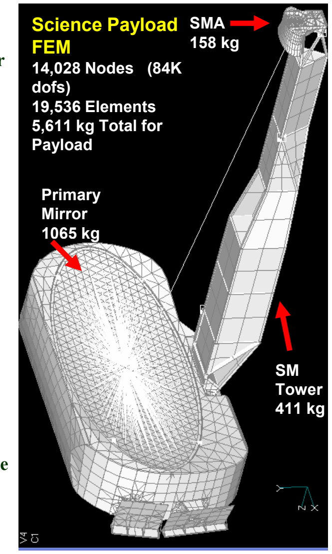
- **Currently, WFE's & Rigid Body motions of optics are within the error budget**
  - for thermal disturbance
- **Toolsets work well so far, and are getting better**
  - Looking forward to significant capability increase shortly
  - Lessons-learned: problems encountered & solved (or worked-around)
- **We need to account for CTE variation in PM**
  - Taking CTE variation into account generally results in higher WFEs than assuming uniform CTE
  - Initial calculations in work
- **Primary Mirror front-to-back delta-temperature drives distortion**
  - Focus & Astigmatism are biggest contributors to WFE
- **Design feasibility looks good: no major road-blocks**
  - Keep in mind the many idealizations made so far: more detail modeling to follow



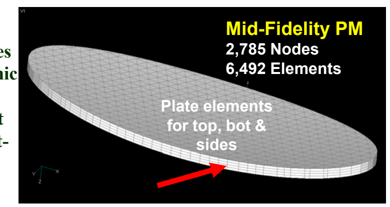


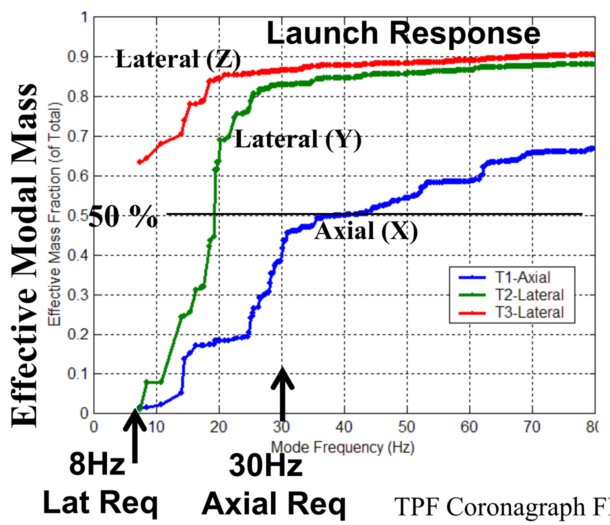
IDEALIZATIONS

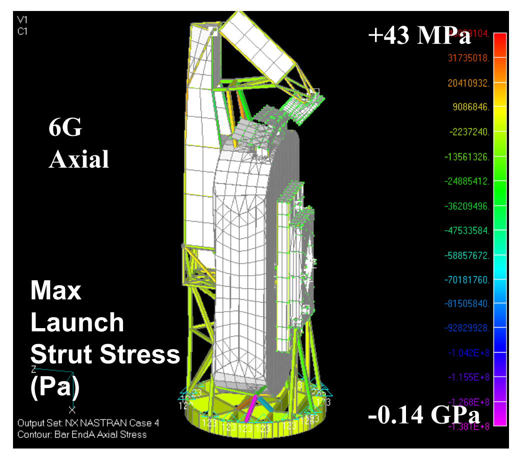
- No hinges, latches or fittings modeled
- No temperature dependent properties
- Uniform properties for like materials
- Lumped & smeared masses for non-struct hardware to match mass-list
- Uniform, linearized model of tensioned membranes to capture geom stiffness



- Mid-Fi PM model captures overall dynamic & thermal distortion, but not local print-thru effects



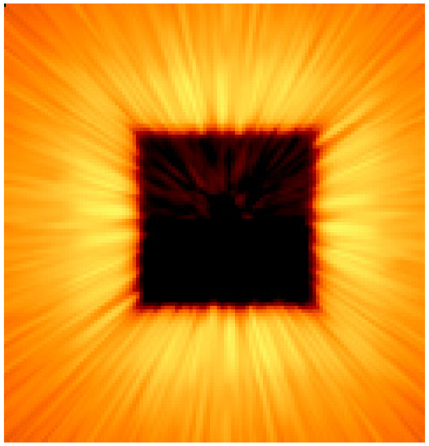




High-Level Requirements

Table 1. TPF-Coronagraph Contrast Error Budget Requirements.

	Requirement	Comment
Static Contrast	6.00E-11	Coherent Terms
Contrast Stability	2.00E-11	Thermal + Jitter
Instrument Stray Light	1.50E-11	Incoherent light
Inner Working Angle	$4\ \lambda/D_{long}$	57 mas at λ=550 nm, D_{long} = 8 m
Outer Working Angle	$48\ \lambda/D_{short}$	1.5 arcsec at λ=550 nm, D_{short} = 3.5 m
Bandpass	500-800 nm	Separate observ. in three 100 nm bands.



HCIT Demonstration of Planet Detection in Broadband Light

The test: Using a band-limited mask, form a dark hole using the Electric Field Conjugation algorithm. Then reset the DM to nominally flat, wait 8 days, and repeat.

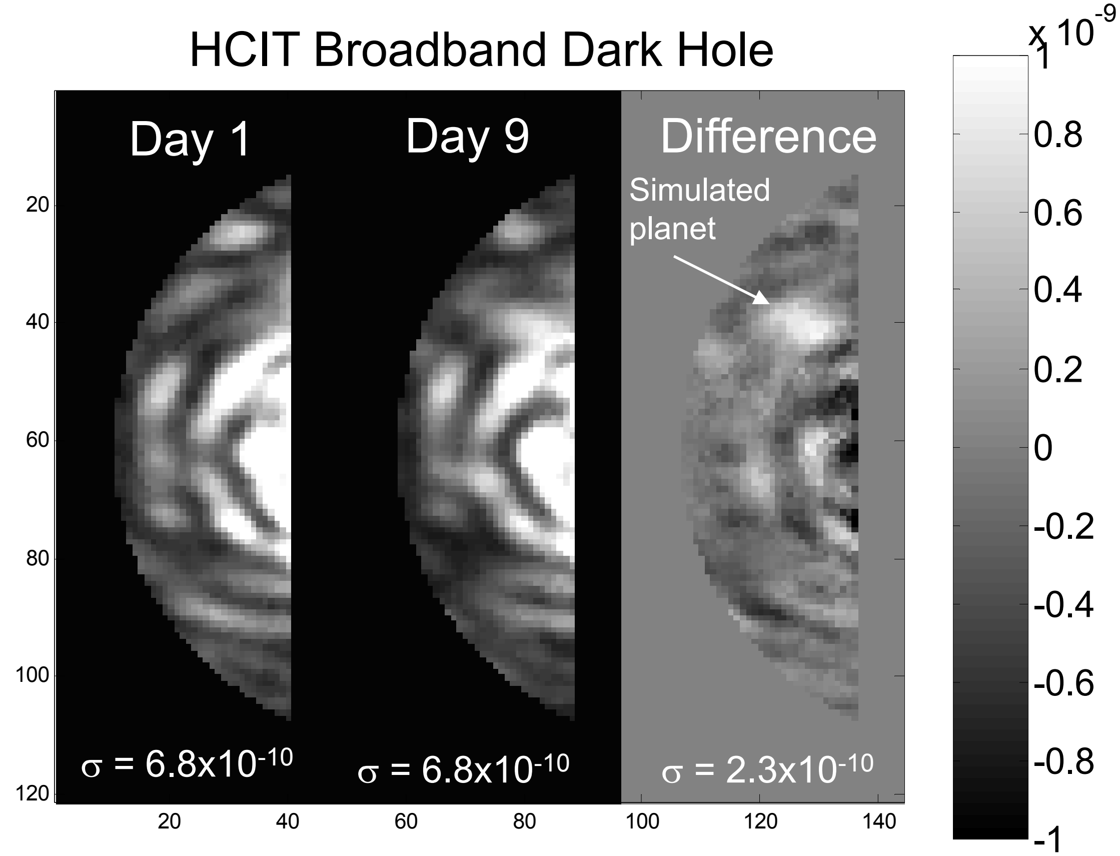
Parameters:

3 filters,
each band 2% wide
Centered on 800, 816, and 832 nm.

D-shaped dark hole:
IWA = 4 λ/D
OWA = 10 λ/D

Add in simulated planet in second data set.
Peak contrast = 1e-9

Sum together the bands to form composite 6% bandwidth images.



Error Budget Structure

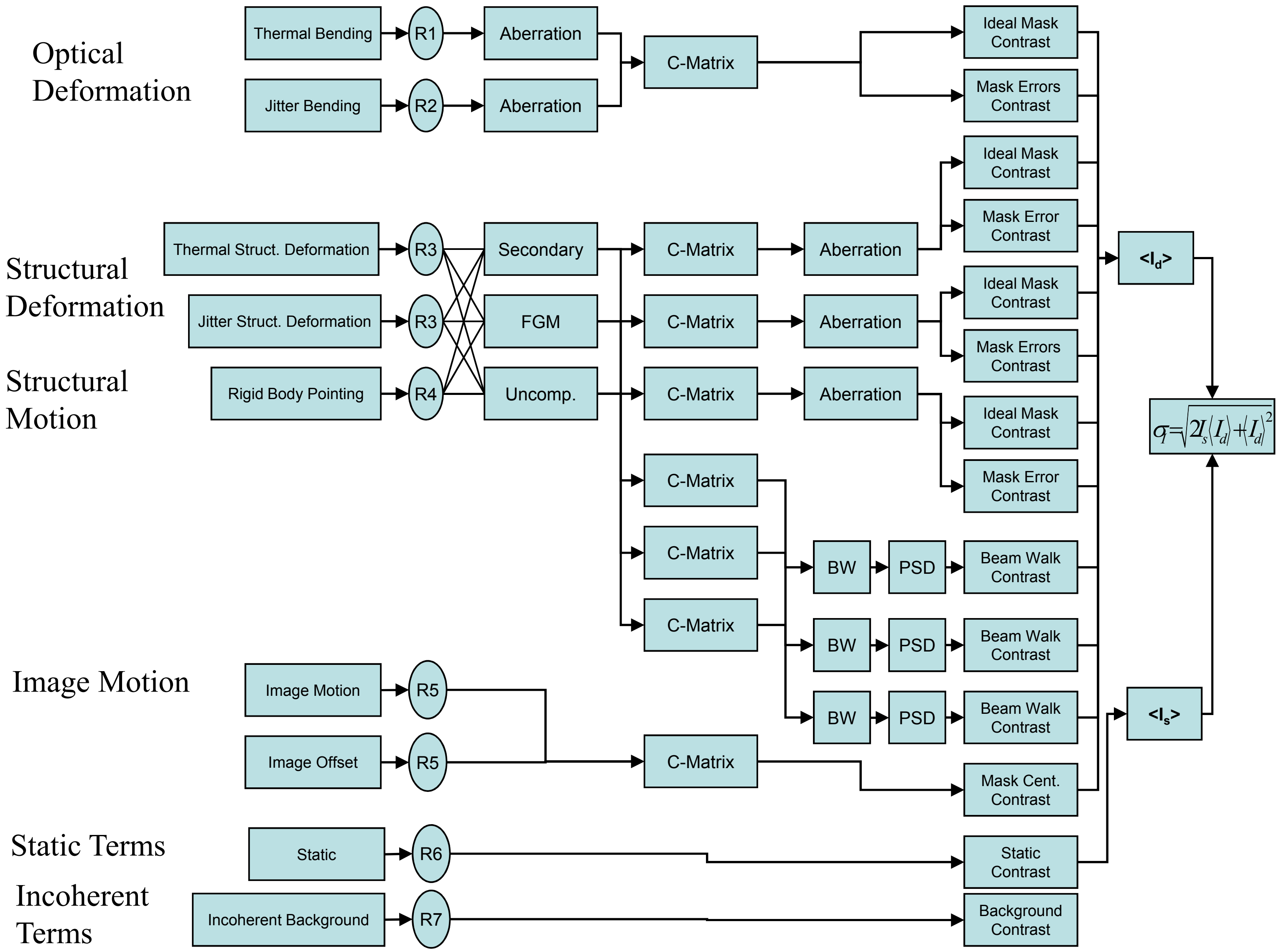
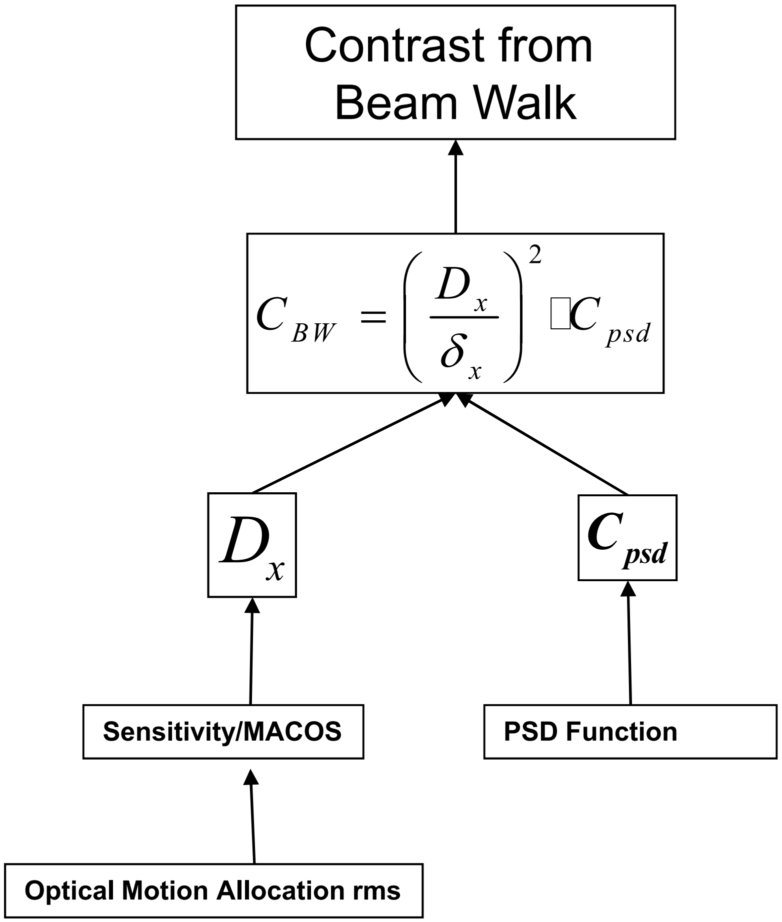


Figure 1. Error Budget Structure. 'C-matrix' is a sensitivity matrix or equation.
R1-R7 are multiplicative reserve factors.

Beam Walk Model



$$C_{psd} = \left(\frac{2\pi}{\lambda} \cdot \sqrt{ \iint 16\pi^2 (\delta_x k_x)^2 \cdot \left[\frac{A}{1 + \left(\frac{\sqrt{k_x^{\ 2} + k_y^{\ 2}}}{k_0} \right)^n} \right] dk_x dk_y } \right)^2$$

Figure 4. Beam walk calculation. C_{psd} is the contrast for a unit value of beam walk, δ_x at a spatial frequency (image plane position) of k_x.. D_x is the beam walk calculated from linear sensitivity matrices applied to allocated translation and tilt motions.

Control Systems

- 3-tiered pointing control
  - Rigid body pointing using reaction wheels or Disturbance-Free Payload
  - Secondary mirror tip/tilt (~ 1 Hz)
  - Fine-guiding mirror (several Hz)
- PM-SM Laser Metrology and Hexapod
  - Measures and compensates for thermal motion of secondary relative to primary.

Pointing Control

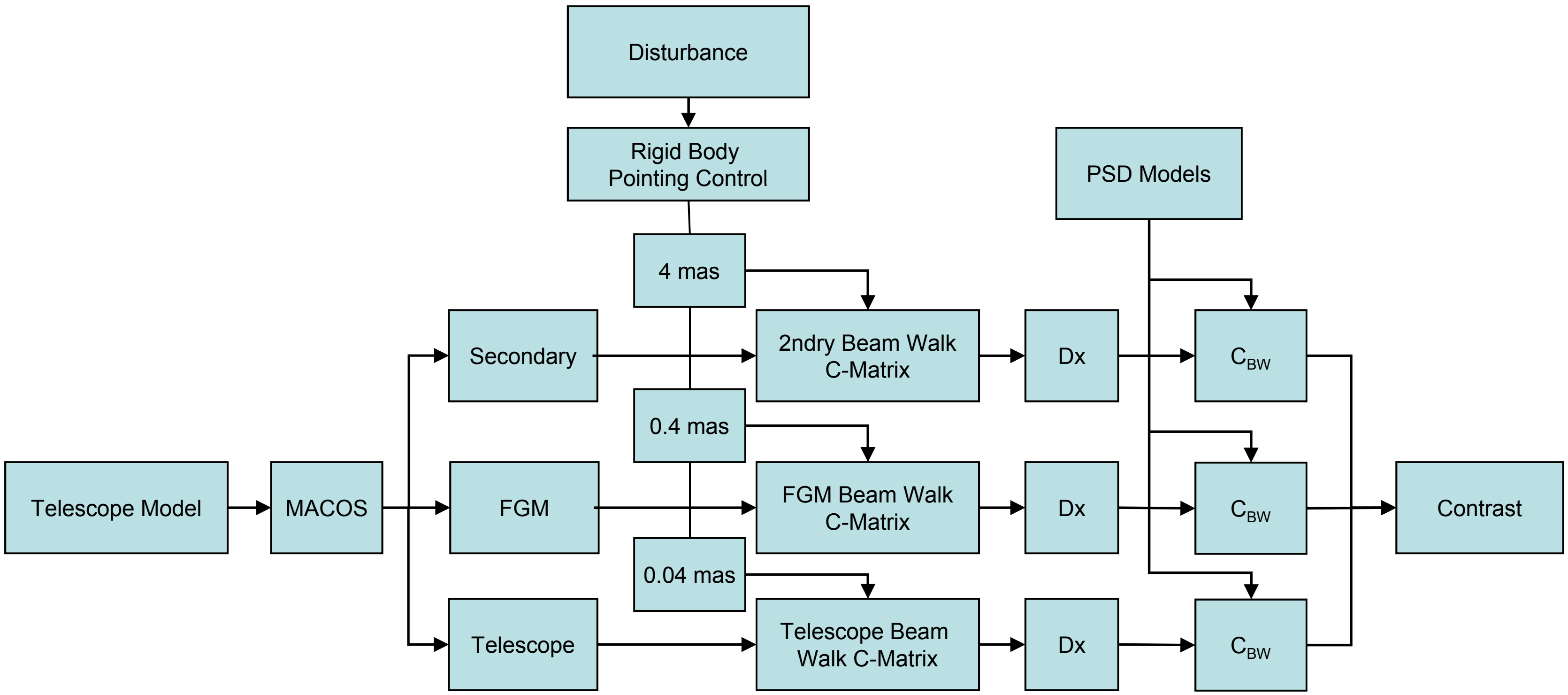


Figure 2. Pointing control. The CEB assumes a nested pointing control system. Reaction wheels and/or a Disturbance Reduction System control rigid body motions to 4 mas (1 sigma). The telescope secondary mirror tips and tilts to compensate the 4 mas motion but has a residual due to bandwidth limitation of 0.4 mas. A fine guiding mirror in the SSS likewise compensates for the 0.4 mas motion leaving 0.04 mas uncompensated.

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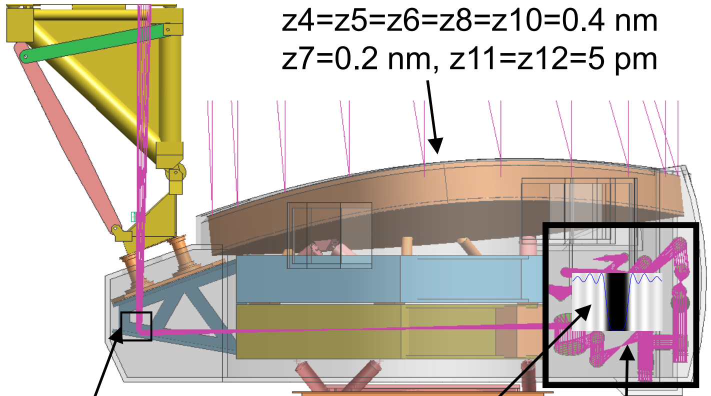
Key Dynamics Requirements



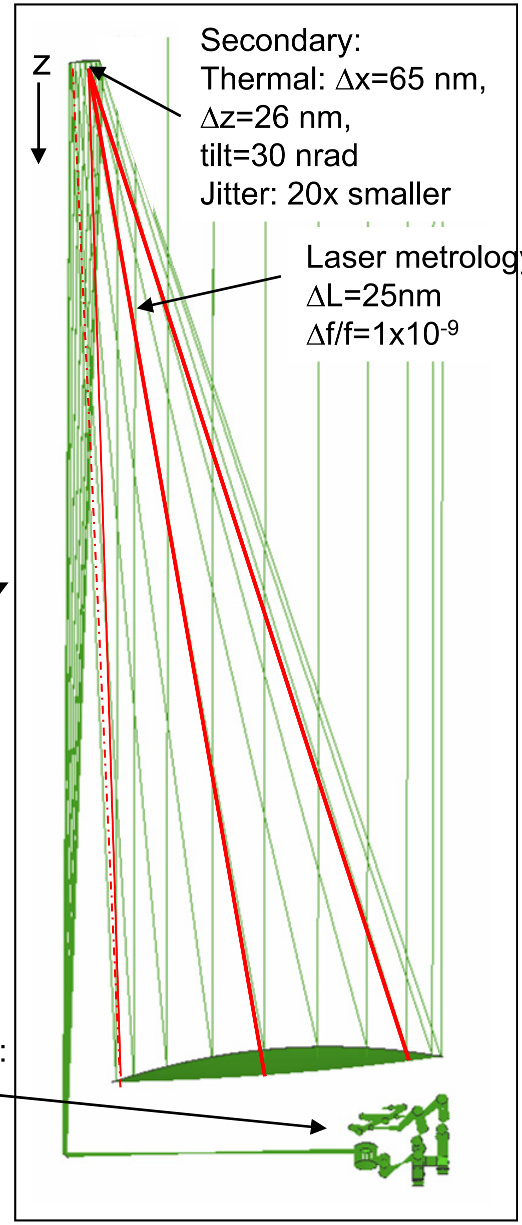


Figure 5. We identify the major engineering requirements to meet the dynamic error budget. Thermally induced translations lead to beam walk that is partially compensated by the secondary mirror. Jitter is partially compensated by the fine guiding mirror.

Iterative Design/Analysis Cycle Process